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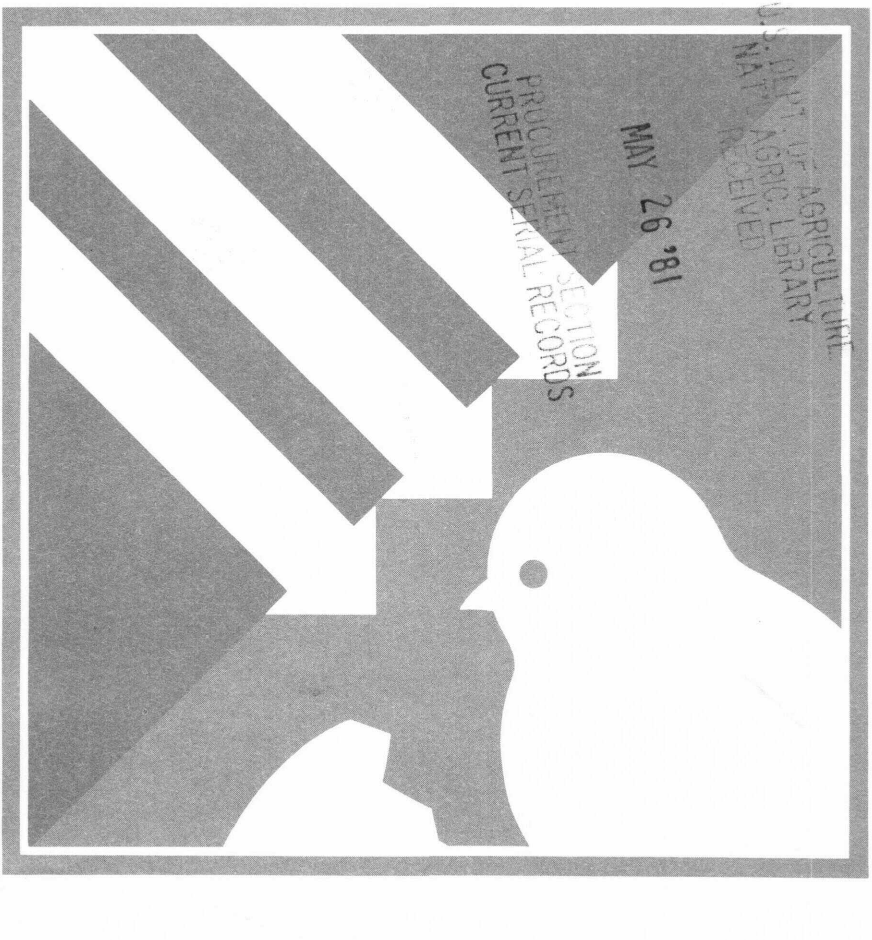

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Solar Heating for Brooding Chickens

By Floyd N. Reece[1]

Modern poultry farming developed when energy was cheap and abundant. Now, as conventional sources of energy become more expensive and less reliable, the heavy dependence on fossil fuels for heat in poultry brooding is a matter of serious concern. Solar energy is a promising alternative fuel source for heating poultry brooding houses.

Research on adapting solar energy technology to poultry brooding operations has been conducted by the Science and Education Administration, U.S. Department of Agriculture, and funded by the U.S. Department of Energy. The heating system described in this bulletin was built and tested at the South Central Poultry Research Laboratory at Mississippi State University, Mississippi State, Miss. It was tested in comparison with a conventionally heated LPG (liquefied petroleum gas) system.

In conjunction with partial-house brooding, precision ventilation control, and improved insulation, the solar heating system in this experiment reduced the amount of energy needed to operate a brooder house by about 90 percent, and consumption of fossil fuel was negligible.

Since the poultry industry in the United States is located mainly in Sun Belt States, solar energy is generally a promising alternative for farmers. From an economic point of view, however, initial investment costs of solar heating systems are high. Therefore, farmers may wish to wait until technical advances lower the cost of solar heating systems or until the prices of fossil fuels rise so much that solar systems become economically competitive.

Solar Versus Conventional Energy Costs

The solar heating system described here is presented so that farmers can consider the options available for heating brooding houses. With a conventional petroleum-based system, the major expense in heating brooding houses is the cost of fuel. LPG is the fuel most often used in brooder operations. Equipment for releasing and using heat from this fuel is readily available and simple to operate. The fuel can be stored indefinitely. The initial cost of an LPG brooder was about $40 in 1979.

With a solar heating system, the fuel is free, but the equipment needed to collect and store solar energy is large and expensive. For example, in Mississippi in 1979, replacing the full heating capacity of a $40 LPG brooder with solar energy equipment required 320 square feet (30 m^2) of solar energy flat-plate collectors. The initial cost of the collectors was about $3,200.

How Solar Heating Systems Work

Solar heating systems are designed to exploit some well-known characteristics of light. Solar energy collectors work because of a natural phenomenon known as the "greenhouse effect." Sunlight enters

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through the clear cover of an energy collector and is trapped when it changes to a longer wavelength type of energy as it strikes the dark surface of an absorber. Then, a heat transfer medium, such as air or water, passes through the collector to absorb the heat energy and to move the energy to a point of use or to storage for later use.

Collectors generally work most efficiently when they are positioned perpendicularly to the angle of incoming solar radiation. A practical approach for collectors is to face them to the south and mount them at an angle from the horizon equal to the local latitude plus 10 to 15 degrees.

A good flat-plate collector will have an efficiency of 40 to 60 percent; that is, it will convert into usable heat about half of the radiation that strikes it. This type of collector will function to some extent even on cloudy or overcast days.

Auxiliary electric or fuel-fired heaters are usually needed to supplement solar systems, and they were used in the experimental system described here. They avoid the expense of building an extra-large solar heating system that would otherwise be needed to meet all contingencies.

A Solar-Heated Brooding System

Figure 1 is a diagram of the experimental solar heating system as it was originally designed to fulfill the heating requirements of brooding and growing broiler chickens in a typical poultry house. This system used a combination of water- and air-type solar heat collectors. In daytime, air heated by air-type collectors passed through polyvinyl ducts and vents into the brooding house, providing direct ventilation and heat to the chicks. Meanwhile, water-type collectors sent heat to a water tank to be stored for nightime use. At night, heat stored in that tank was moved to an automotive-type radiator while fans circulated air through the radiator to adsorb and send heat to the chicks. This combination system was intended to supply all of the heat needed each day and to store enough energy to supply the heat needed each night under normal midwinter conditions in Mississippi. Here are some factors related to the system's design:

Brooding Requirements—Temperatures of 85-95°F (29-35°C) are needed for the survival of young chicks in their first 2 weeks (fig. 2). Progressively lower temperatures are needed during the following 6 weeks. The decreasing temperature needs of growing chickens coincide with increased heat output of the birds. Thus, heat demand is reduced with age, assuming no change in outside conditions.

Space—The brooding area in this experiment was restricted to 25 percent of the total floor space of the poultry house for the first 2 weeks and to 50 percent for the second 2 weeks (fig. 3). After 4 weeks, the entire house was used. Dimensions of the poultry house were 36 by 80 feet (11 by 24 meters).

Insulation—Early in the experiment, the brooding area was partitioned with polyethylene curtains. Rigid-foam insulation board later proved to be more efficient (fig. 4). (A strip of fiberboard or cardboard can be added across the bottom to prevent chicks from pecking holes in the foam.)

Air Movement—Continuous ventilation was provided to limit carbon dioxide in the air to 5,000 parts per million and the relative humidity to less than 70 percent. Polyvinyl ducts carried heated air to the growing area where small vents in the ducts provided even distribution of the airflow (fig. 5). The fresh airflow rate for each chick was 0.06 cubic feet a minute (1.7 liters/min) in the first week, 0.12 ft^3/min (3.4

Figure 1 — Diagram of the solar heating system as first used for the brooding house for chickens.

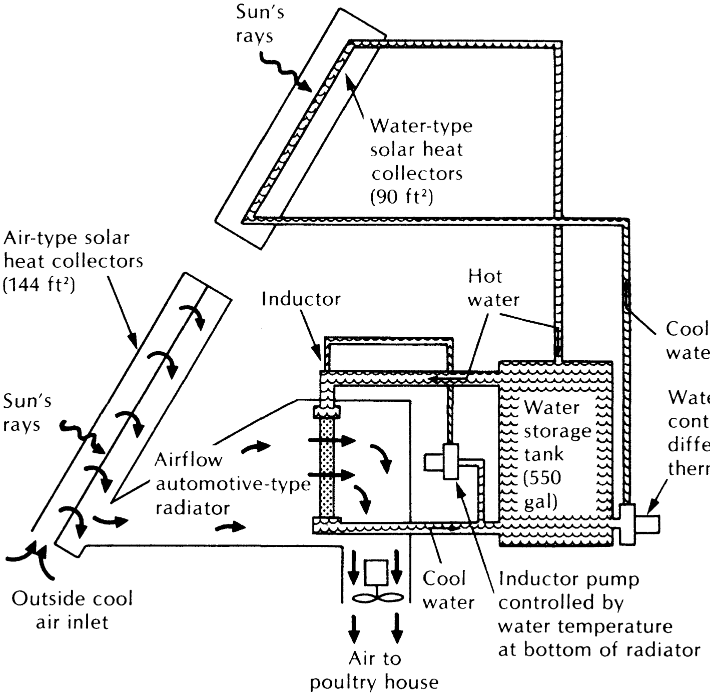


Figure 2 — Brooding temperatures for chickens.

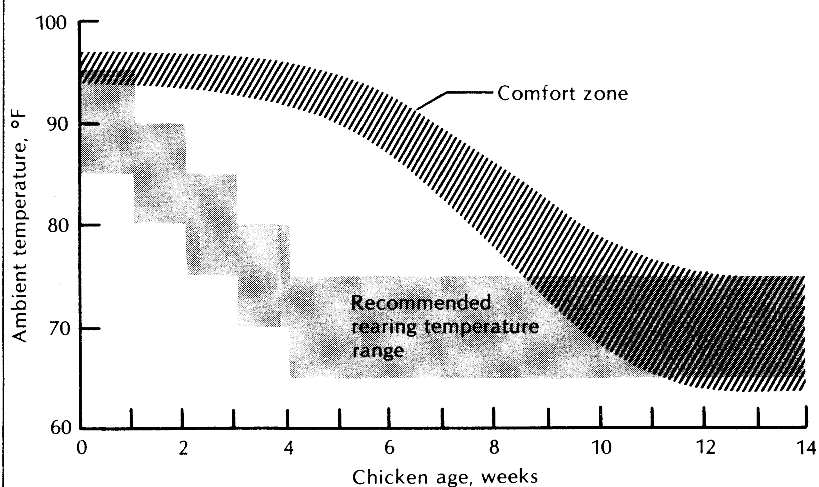
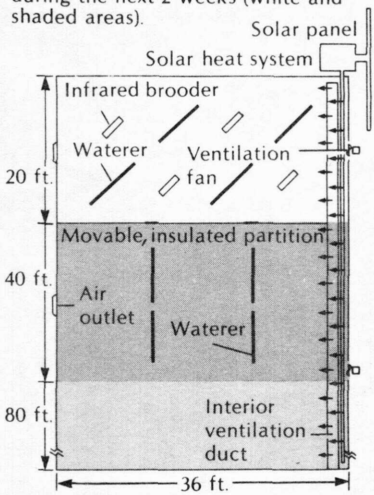


Figure 3— Floor plan of brooder house showing arrangements for one-fourth of the house for the first 2 weeks of rearing chickens (white area) and one-half during the next 2 weeks (white and shaded areas).



l/m) in the second week, and 0.18 ft³/min (5.1 l/min) after the second week.

Thermostatically controlled electric fans were used for additional ventilation when temperatures in the growing area exceeded 85°F (29°C) in the first week, 80° (27°) in the second week, and 70° (21°) after the third week. The thermostatic control used for the auxiliary ventilation system was a time-proportioning type. It was also used for the auxiliary electric heaters or gas stoves. The control operated the ventilation fans or the heaters for a percentage of each 5-minute period as needed to maintain the desired temperature in the house.

The auxiliary ventilation system, which was set to operate in response to temperatures above

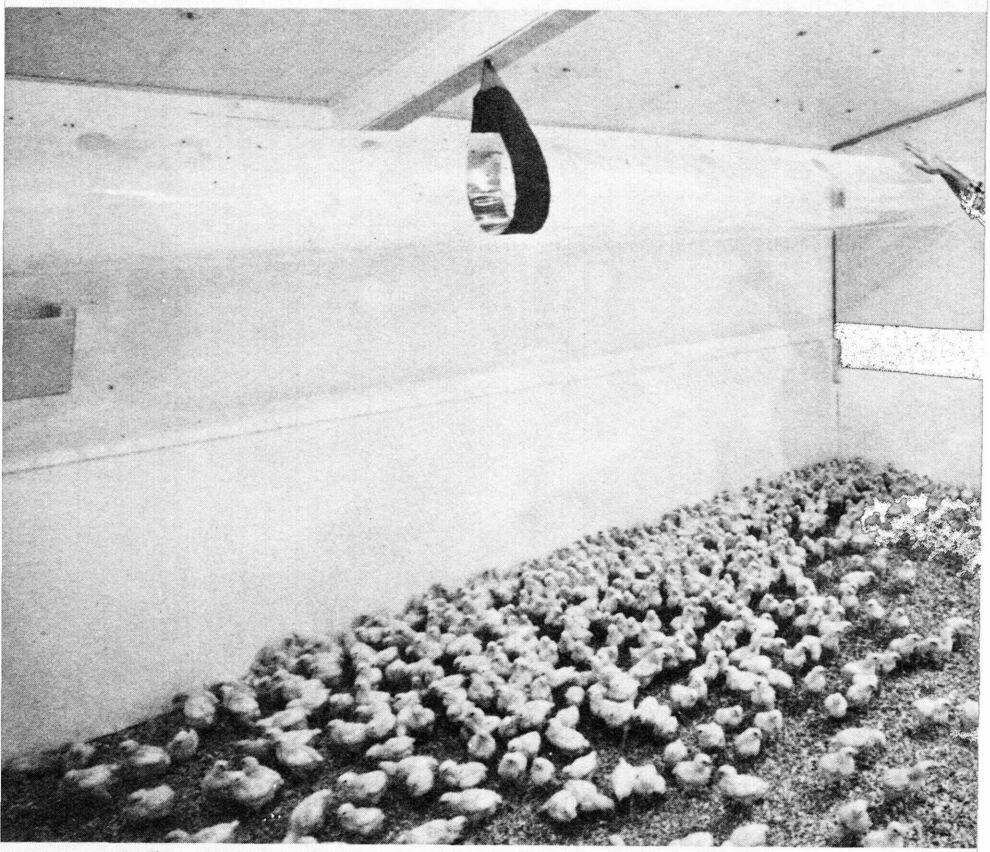
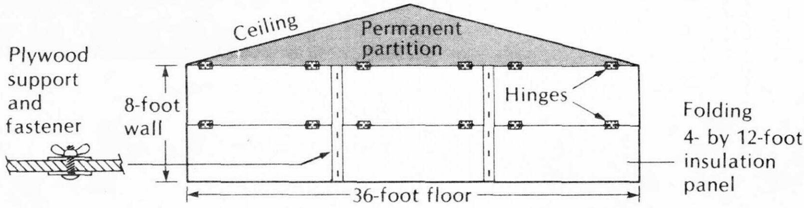


Figure 5— Broiler house interior showing the plastic duct used to introduce solar-heated right rear. (1076x1416-8A)

Figure 4—Side view of partition used to restrict the extent of the brooder house heated in the first weeks of rearing chickens. The partition may be folded up when the chickens outgrow the limited space.



certain levels, was started 75 percent more often with the solar heating system than with the conventional system.

Collector Design—The basic designs of flat-plate collectors for systems that use water and air as heat transfer mediums are shown in figure 6.

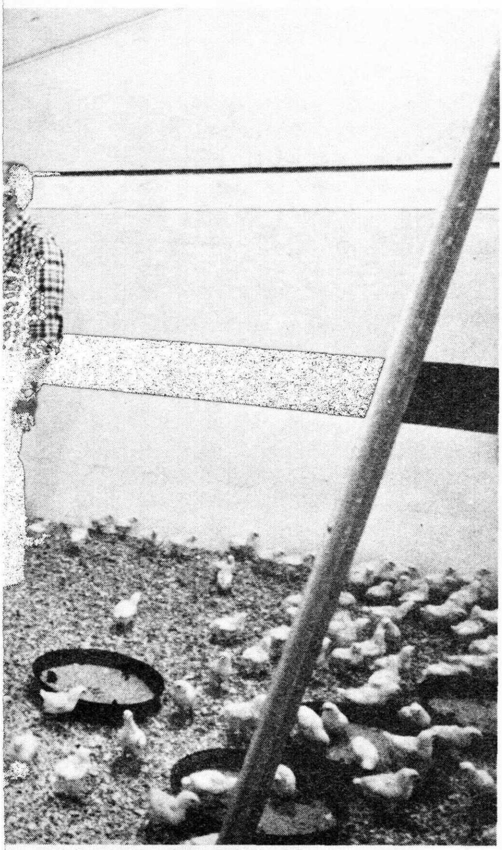
Figure 7 shows a side view of the air collector that was designed and built for the experimental broiler house. For each 1,000 chickens, an area of 73 square feet (6.9 m^3) of collector surface was used. Baffles forced the air to follow a serpentine path through the collector in order to increase the air turbulence and thus improve the rate of heat transfer.

The experimental collector was about 25 percent more efficient than most of the air type-collectors on the market in 1979.

Diagrams of the air and water solar collectors are in figure 8. In daytime, air from the collectors passed directly into the ventilation system. Water was circulated, when the sun was shining, from the collectors to the storage tank and back by an electric pump controlled by a thermostat that sensed when the sun's heat was available. At night, water circulated through the radiator by thermo-siphon action, a pump-free system which is based on the natural tendency for hot water to rise.

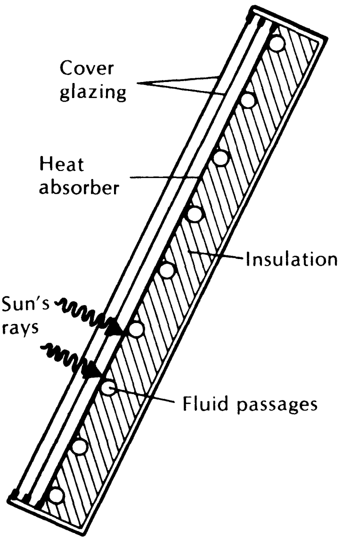
At midday, when the air collectors provided more heat than was needed in the house, water moved through the radiator in the opposite direction from its movement at night.

Operational Modifications—After several months of testing and observation, several changes were introduced to improve the performance of the overall system and its



ation air. Part of the insulated partition is shown at

Figure 6—Side views of flat-plate heat collectors for water- and air-based solar systems.



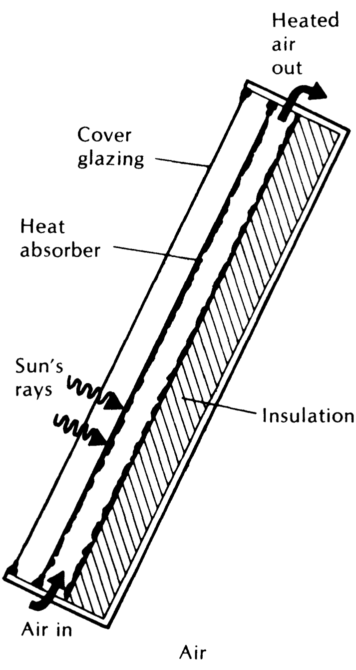
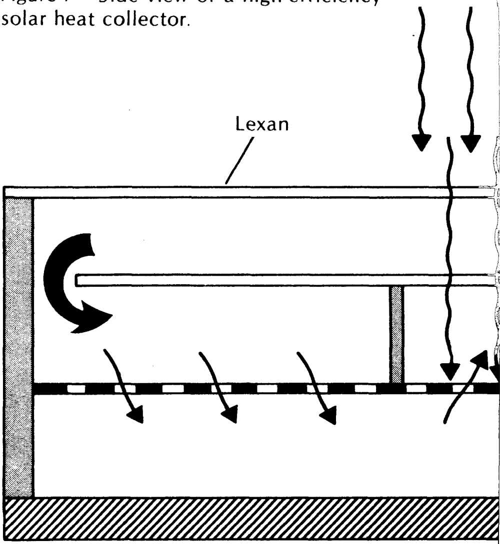


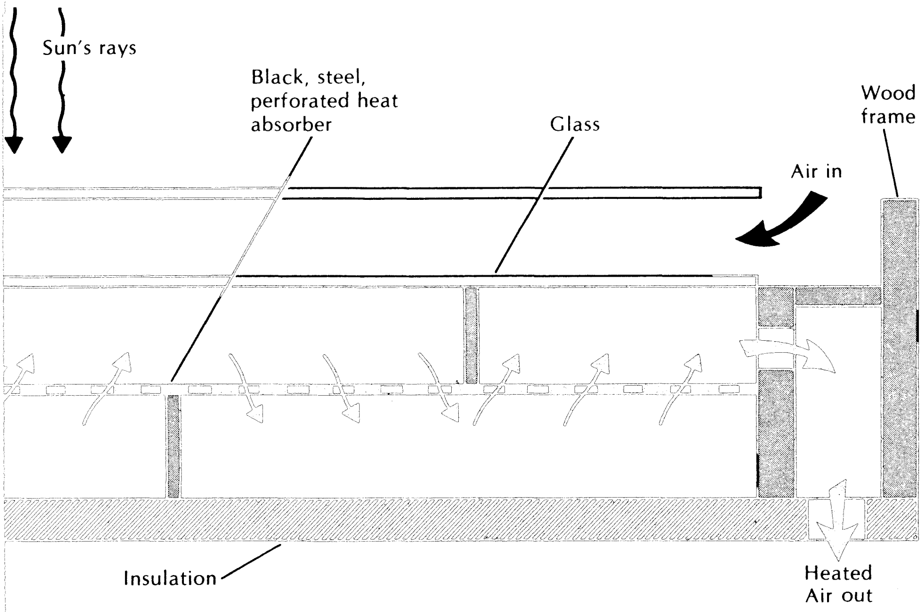
Figure 7—Side view of a high-efficiency solar heat collector.



individual parts. Initially, 40 percent of the collectors used water as the heat transfer medium, and 60 percent used air. Later, because efficiencies were different than anticipated, a higher percentage of water-type collectors were used.

For the size of brooding house used, it was found that a water tank with storage capacity of 800 gallons (3,028 liters) was necessary. Also, to provide additional protection from freezing, the water tank was closely coupled to the collectors, and all associated plumbing and pumps were relocated so they were within the water tank (fig. 9).

In theory, the thermo-siphon action of the water circulating between the storage area and the radiator should have continued until the temperature dropped to about 40°F (4°C). Actually, the movement ceased sooner—at 70° (21°)—and water in the exposed radiator froze. An inductor was installed to prevent that from happening.



Selection Decisions

Kind of Collector—Selecting the medium (air or water) to use for transferring energy is by far the most important decision in building a solar heating system. Once the transfer medium has been selected, other decisions regarding a system's design and components are affected by the nature of the medium. The system devised for the experimental system combined the advantages of water and air mediums and had two separate collection systems. But most solar heating systems use one medium or the other.

Materials used in building a solar heating system must be able to withstand high temperatures. Sooner or later, either through a malfunction or when the heating system is shut down for the summer, solar collectors will be exposed to sunlight at a time when the transfer medium is not circulating and cooling them. As a result, the collectors may be damaged or, with some insulating materials or plastics, may even catch fire. Some plastics will not provide the "greenhouse effect," as they allow too much heat to escape. So before purchasing, check the manufacturer's description of the material's performance.

Storage—For collector systems using water as the transfer medium, a well-insulated water tank is recommended for storage. For air-type collectors, a large, insulated area filled with small rocks or crushed stone is recommended.

Water is relatively inexpensive and readily available as a storage medium. A smaller volume of water is needed to store a given amount of heat compared to mediums used to store heated air. For example, a tank for heated air composed of limestone rock, which has a specific heat factor of 0.22 and weighs more than water, must be made almost three times larger than a water tank to provide the same energy storage

capacity. Heating generally can also be more easily manipulated with water than with air.

Using water, however, has several disadvantages. First, waterflow to the collectors is generally set to begin when the temperature inside the collector is about 5°F (3°C) higher than the water temperature in the storage tank, whereas air-type collectors begin to provide usable heat as soon as the temperature inside the collector exceeds the temperature at the air intake for the ventilation system. In practice, therefore, water-type collectors supply heat for about 2 hours less in the morning and again in the evening than air-type collectors.

Another factor to consider is that water freezes. On a cold, clear night, a collector may radiate heat to the outside so efficiently that freezing happens, even though the surrounding air temperature is several degrees above freezing. Thus, water must be drained from all exposed parts at night. Antifreeze can be used to avoid freezing, but it increases operating costs.

Metal parts must be chosen and combined with special care in water systems to avoid losses from corrosion or galvanic reactions. Anticorrosive agents are needed. Sodium chromate, which was used to protect metal in the experimental system's collectors, is toxic, and its proper disposal is difficult.

The water used in solar heating systems should be tested beforehand. It may need treatment to eliminate corrosive elements. Once water is in the system, provisions should be made to prevent oxygen from entering the storage tank, because it would have a corrosive effect on the metal parts.

Combining Heating Systems—To achieve optimum efficiency, the

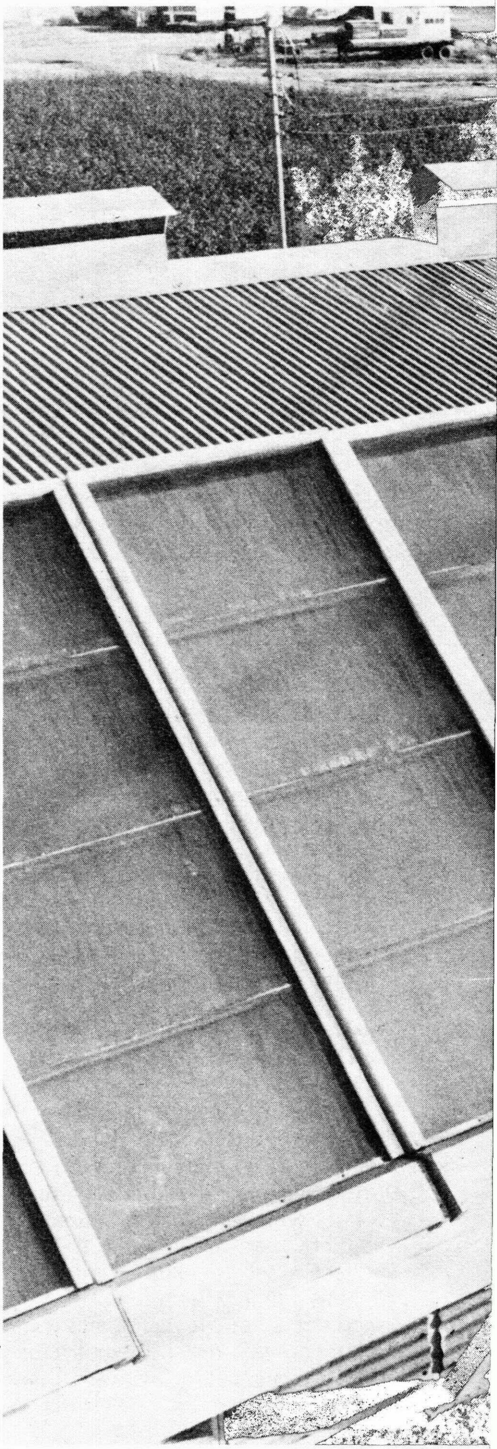
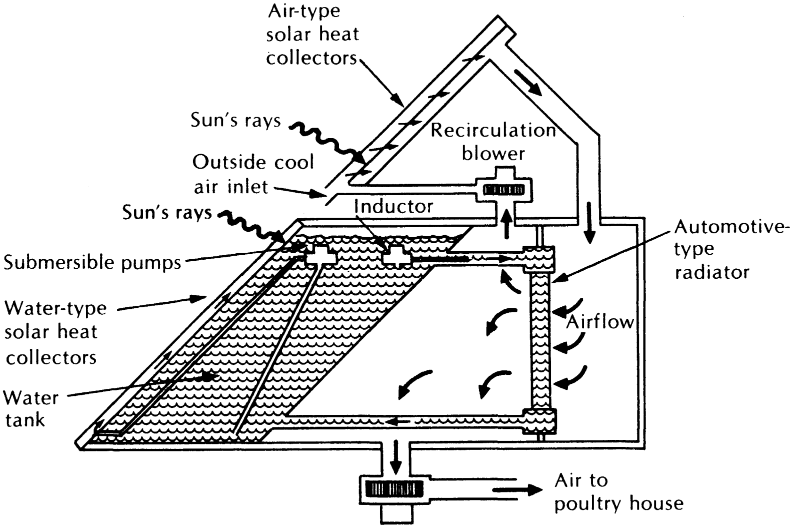


Figure 8—Air-type collectors (left) were used to sup
night. The researcher is checking a pyranometer, w

t to the brooder in daytime; water-type collectors (right) were used to store heat for use at
sures solar radiation that strikes heat collectors. (1076x1415-14A)

Figure 9—Diagram of modified experimental solar heating system used to prevent freezing of water-type equipment and to improve efficiency.



solar heating system described in this bulletin combined the advantages of air collectors with water collectors for storage.

Many other combinations and adaptations are possible. Some farmers might consider using solar heat in the daytime and conventional heat at night, which would eliminate the need for storage of solar energy. Depending on the design of a poultry house, considerable heat may be retained from the daytime in the walls and floor.

Site Characteristics—Specific site characteristics may make a particular farm unsuitable for solar heating systems. A strong, constant wind, which often occurs near a large body of water, may cause so much heat to be lost from the collectors by convection that standard calculations of system size and expense would not apply.

Solar Heating in Perspective

Solar heating systems become economically competitive with conventional fuel-fired heaters only on a long-term basis. The experimental system described in this bulletin produced an impressive decrease in the need for fossil fuel.

In a conventional LPG-heated system, use of energy conservation techniques reduced annual LPG consumption from 70 to about 30 gallons (265 to 114 liters) for each 1,000 chickens. With the same techniques, the solar heating system reduced annual LPG use to about 8 gallons (30 liters).

Sound planning and careful selection of materials, preferably materials guaranteed or tested by reputable firms, are essential in building a solar heating system. Information on adapting solar energy technology to poultry farming can be obtained from State land-grant universities or from the National Solar Heating and Cooling Information Center, P.O. Box 1607, Rockville, Md. 20850.

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